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A. Objective Analysis
The automatic process of transforming of irregularly distributed observed data from different geographic locations at various times to numerical values at regularly spaced grid points at fixed times is called *objective analysis*. In the earlier days of numerical weather prediction, the two-dimensional fitting of polynomial was applied to observational data in an area surrounding a grid point at which the value of analysis is required. Polynomial fitting is suitable for processing relatively dense and redundant data, but it often gives unreasonable results in data of sparse areas.
More recent procedures of objective analysis practiced at most of the operational forecasting centers consist of the steps schematically described in Fig. 2. Most observed data are collected worldwide every 6 hours, say 00, 06,12 etc. UTC (Coordinated Universal Time), and are blended into forecast values appropriate to the map time by the process referred to as *data assimilation*. The basic process of data assimilation, indicated by the box enclosed by dashed lines in Fig. 2, consists of two steps: One is objective analysis and the other is called *initialization*. The step of objective analysis is carried out by statistical interpolation by taking into account all of the available observations plus other prior information. Short-term forecasts from the previous analysis cycle are used as prior information and are referred to as background fields.

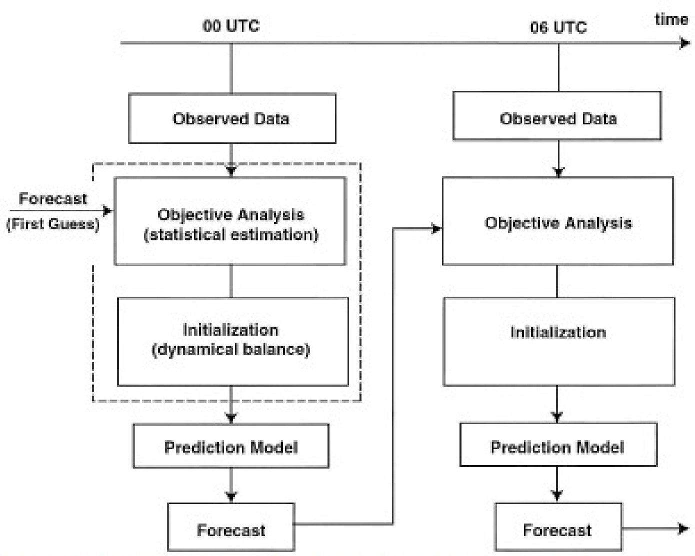

FIGURE 2 Schematic diagram for atmospheric forecast–analysis system. The two processes in the square enclosed by dashed lines can now be combined in the four-dimensional variational data assimilation using a continuous stream of observed data. See text for details.

B. Concept of Initialization
The solutions of primitive equation models correspond to two distinct types of motion. One type has low frequency.
Its motion is quasi-geostrophic and meteorologically dominant. The other corresponds to high-frequency gravity-inertia modes. The amplitude of the latter type of motion is small in the atmosphere. Hence, it is important to ensure that the amplitudes of high-frequency motions are small initially and remain small during the time integration when the primitive equations are solved as an initial value problem. The process of adjusting the input data to ensure this dynamical balance is called *initialization*.
Solution to the initialization problem was central to the successful transition in forecast practice from the use of

quasi-geostrophic models to primitive equation systems during the 1970s. Since gravity-inertial motions are filtered out in quasi-geostrophic models, no special procedure was necessary and the objectively analyzed data could be used immediately as the input data to quasi-geostrophic models. Actually, there is an interesting history that led to solution of the initialization problem that is equivalent to the quest of understanding what the primitive equation forecast system really is. A promising break came with the advent of so-called *nonlinear normal mode initialization* (NNMI) during the latter part of the 1970s.